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CTEC CALIBRATION CENTER

INSTRUCTION MANUAL for

THRULINE®
model 4311
RF Directional Wattmeter

28

INSTRUCTION MANUAL

Thruline

WATTMETER

MODEL 4311

BIRD ELECTRONIC CORP.
CLEVELAND, OHIO

THO IN U.S.A.

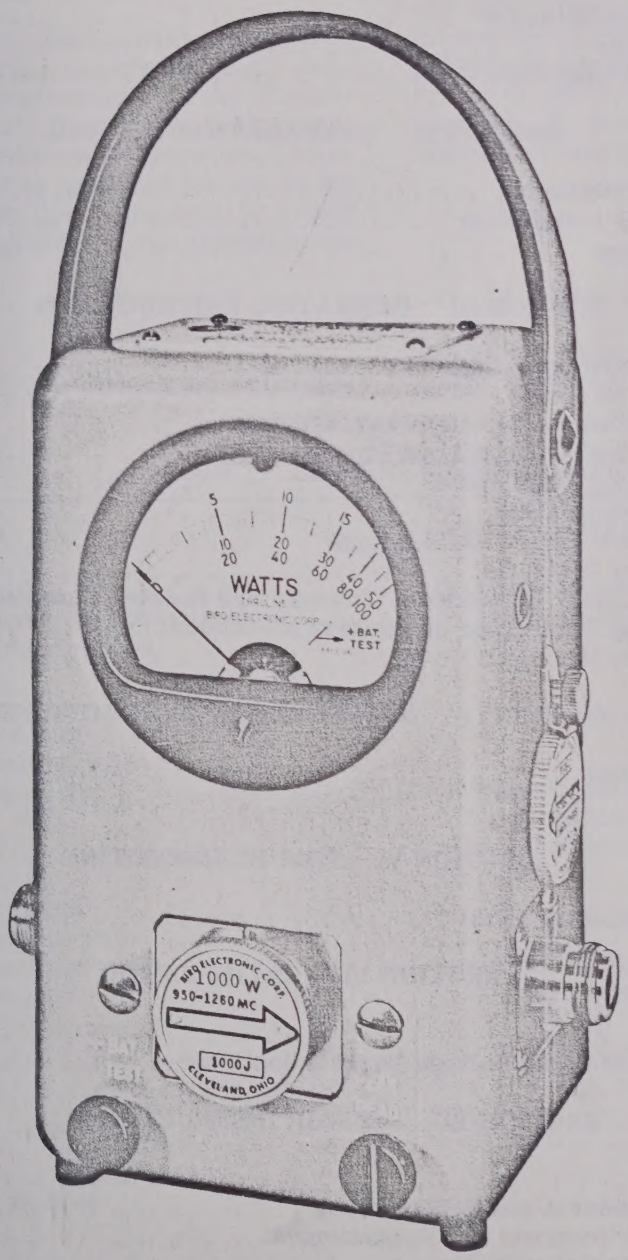

Figure 1-1. Thruline Wattmeter Model 4311

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SECTION I
INTRODUCTION AND DESCRIPTION

1-1. SCOPE

1-2. This technical manual provides operation, service, maintenance, troubleshooting, calibration, and repair instructions for the Thruline Wattmeter Model 4311 (see figure 1-1), manufactured by Bird Electronic Corporation, Cleveland (Solon), Ohio. It is prepared for use by the technicians to whom this equipment is issued and who are responsible for its operation and maintenance.

1-3. PURPOSE

1-4. The Model 4311 is a directional wattmeter which measures and monitors RF power flow and load match in coaxial lines. It is used for measurement of CW, AM, FM, SSB, TV, and pulsed transmitter outputs, or practically any types of RF transmission in 50-ohm coaxial systems. It indicates either average or peak power as required.

1-5. LEADING PARTICULARS

1-6. Leading particulars for the Thruline Wattmeter Model 4311 are given in Table I.

TABLE I. LEADING PARTICULARS

Measuring medium	RF transmission in 50-ohm coaxial systems
RF power ranges:	
Average (CW) mode	1 watt to 10 kilowatts (±0.05 of full scale)
Peak-pulse or envelope-power mode	1 watt to 10 kilowatts (±0.08 of full scale)
Frequency Range (either mode)	0.45 to 2300 megacycles/sec.
Pulse Parameters:	
Square pulses:	
Minimum duty factor	1.0×10^{-4}
Minimum repetition rate	30 pps
Minimum pulse width	0.4 microseconds at 100-2300 megacycles/sec.
	1.5 microseconds at 26-99 megacycles/sec.
	15 microseconds at 2-25 megacycles/sec.
Gaussian Pulses:	
Minimum duty factor	1.0×10^{-3}
Minimum repetition rate	30 pps
Minimum pulse base width (at 10% of height)	3 microseconds at 26-2300 megacycles/sec.
	15 microseconds at 2-25 megacycles/sec.
Line Connectors:	
Standard	Quick-Change, Female "N" type
Options	Any common RF type
Weights:	
Meter	3.4 lbs
Plug-in element	3 oz
Basic Overall Dimensions:	
Height	7 in.
Width	4 in.
Depth	3 in.
Battery Requirements:	
5.40 V	Mallory TR-164R or equal
12.60 V	Mallory TR-169 or equal

1-7. DESCRIPTION

1-8. The wattmeter is a highly portable unit, encased in an aluminum housing fitted with a leather carrying strap. It is provided with a removable back panel to allow access to the operating components. It has four rubber bumpers on the base and four rubber bumpers on the back to facilitate use in either an upright or flat-laying position. The meter is shock mounted on the front panel. It has three scales to facilitate use with any of the available elements.

1-9. A line section casting, through which the RF transmission flows, is mounted in the housing so that one threaded end extends from the right side of the housing and the other threaded end extends from the left side. These ends are quick-change type connectors secured to the line section body with four screws. Transmission lines connect to these threaded ends through mating connectors. Line connections can be reversed without affecting the accuracy or operation of the unit. A socket in the line section casting is provided for the insertion of the plug-in elements. This nickel-plated brass line section is a precision unit that provides unimpaired impedance of the RF coaxial line into which it is inserted.

1-10. The wattmeter uses plug-in elements of the required frequency and wattage range to sense the transmission through the line section. These cylindrical elements are interchangeably inserted into the socket on the front face of the housing below the meter. By use of these plug-in elements the wattage range and frequency range is greatly expanded over those which could be provided in a fixed-element type meter. The plug-in elements incorporate the coupling circuits which sample the traveling waves in the line section. The elements are retained by a small catch at the lower left of the element flange of the line section. This catch assures proper retention and contact of the element in the line section.

1-11. Plug-in elements are available in wide range of frequencies and wattages. Most of them are designed to read both average and pulse-mode wattage. Some of them are designed exclusively for pulse-mode reading operation. Available plug-in elements are listed in Table II. The plug-in elements of earlier average-reading-only wattmeters can be used with the average- or peak-reading Model 4311 for reading wattage in either average or peak modes of operation.

1-12. In the Model 4311, batteries are mounted inside the rear cover of the wattmeter. Battery types used are listed in Table I, Leading Particulars. These batteries power the amplifier section during peak-reading operation. The amplifier is mounted within the housing.

TABLE II. STANDARD PLUG-IN ELEMENTS

Use	Frequency (MCS)	Power Ranges (watts)
Average or pulse mode	0.45 - 2.5	1000, 2.5kW, 5kW, 10kW
	2-30	50, 100, 250, 500, 1000, 2500, 5000
	25-60, 50-125, 100-250, 200-500, 400-1000	5, 10, 25, 50, 100, 250, 500, 1000
	60-80, 80-95, 95-125, 110-160, 150-250, 200-300, 275-450, 425-850, 800-950	1 watt
	60-80, 80-95, 95-150, 150-250, 200-300, 250-450, 400-850, 800-950	2.5 watts
	950-1260, 1100-1800, 1700-2200, 2200-2300	1, 2.5, 5, 10, 25
Pulse mode only	25-60, 50-125, 100-250, 200-500, 400-1000	2.5kW, 5kW, 10kW
	950-1260	50, 100, 250, 500, 1000, 2.5kW. 5kW

1-13. THEORY OF OPERATION

1-14. The operation of this wattmeter is based on the traveling wave concept of RF transmission. As RF power is applied to a transmission line, there is a forward wave traveling from the transmitter to the load, and a reflected wave traveling from the load to the transmitter. The closer the load is matched to the transmission line, the smaller the reflected wave will be. To determine the watts dissipated in the resistance, it is necessary to determine the wattage of the forward wave and the wattage of the reflected wave. The difference between the two will indicate load power.

1-15. In the traveling wave concept, VSWR (voltage standing wave ratio) has become a widely used tool. The standing waves which are produced by interference between the forward and reflected waves do not affect the readings of the wattmeter, since the wattmeter reads only traveling waves. However, after the percentage of reflected power $\left(\frac{\text{Watts Reflected}}{\text{Watts Forward}}\right) \times 100$ is determined, the VSWR (voltage standing wave ratio) can easily be determined by use of graphs (figures 3-2 and 3-3), without requiring the use of unwieldy, expensive, slotted line equipment. However, many users find that the $\frac{\text{Watts Reflected}}{\text{Watts Forward}}$ ratio is a more useful tool than VSWR.

1-16. When the wattmeter is connected into the system, the transmission is directed through the meter line section, which is a short, uniform section of air line that provides unimpaired impedance of the RF coaxial line into which it is inserted. When the plug-in element is installed into the socket in the line section, the RF waves traveling through the line produce energy in the coupling circuit of the plug-in element by inductance and capacitance (see figure 1-2). The inductive currents will flow according to the direction of the traveling waves producing them. The capacitative portion of these currents is independent of the traveling waves. It is therefore apparent that the current produced from the waves traveling in one direction will add in phase, while the current produced from the waves traveling in the opposite direction will subtract in phase. The arrow on the plug-in element indicates the additive direction of wave travel. The element is so designed that the wave components traveling in the opposite direction of the arrow will cancel each other out almost completely, making the element highly insensitive to the reverse wave direction. Because of the highly directional characteristics of the element, the resultant

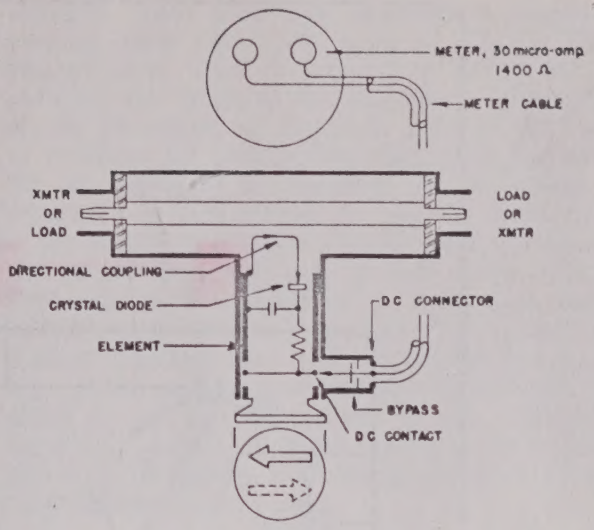


Figure 1-2. Wattmeter Average-Reading Operation, Schematic Diagram

direct current which is sensed by the microammeter indicates the power level of only the RF waves traveling in the arrow direction.

1-17. The plug-in element is designed so that it can be rotated 180 degrees in its socket in the line section. When it is rotated, the meter will indicate the wattage in a direction opposite that of the initial reading, so that if the forward direction power was read first, the reflected direction power will be read after the plug-in element is rotated. The energy resulting from the inductively coupled component of the forward wave will bring about cancellation as described above.

1-18. Besides reading average power as described above, Wattmeter Model 4311 is designed to read peak power when the PEAK button is depressed. This is accomplished by use of the battery-powered amplifier system shown in figure 1-3. Diodes CR1 and CR3 are installed in the battery circuit to protect the amplifier against incorrect installation of the batteries. The battery check circuit is energized when the pushbutton of switch S2 is pressed. If the voltage of the 12-volt battery is within the limits necessary to properly operate the amplifier circuit, the needle of the meter will deflect beyond the battery test mark on the meter. If it fails to reach the mark, the batteries require replacement. The battery test circuit reads only the output of the 12-volt battery, but experience has indicated that the life of the 6-volt battery exceeds that of the 12-volt battery. Replacement of the two batteries simultaneously will assure that sufficient battery power will be available when the meter indicates in the required battery test range.

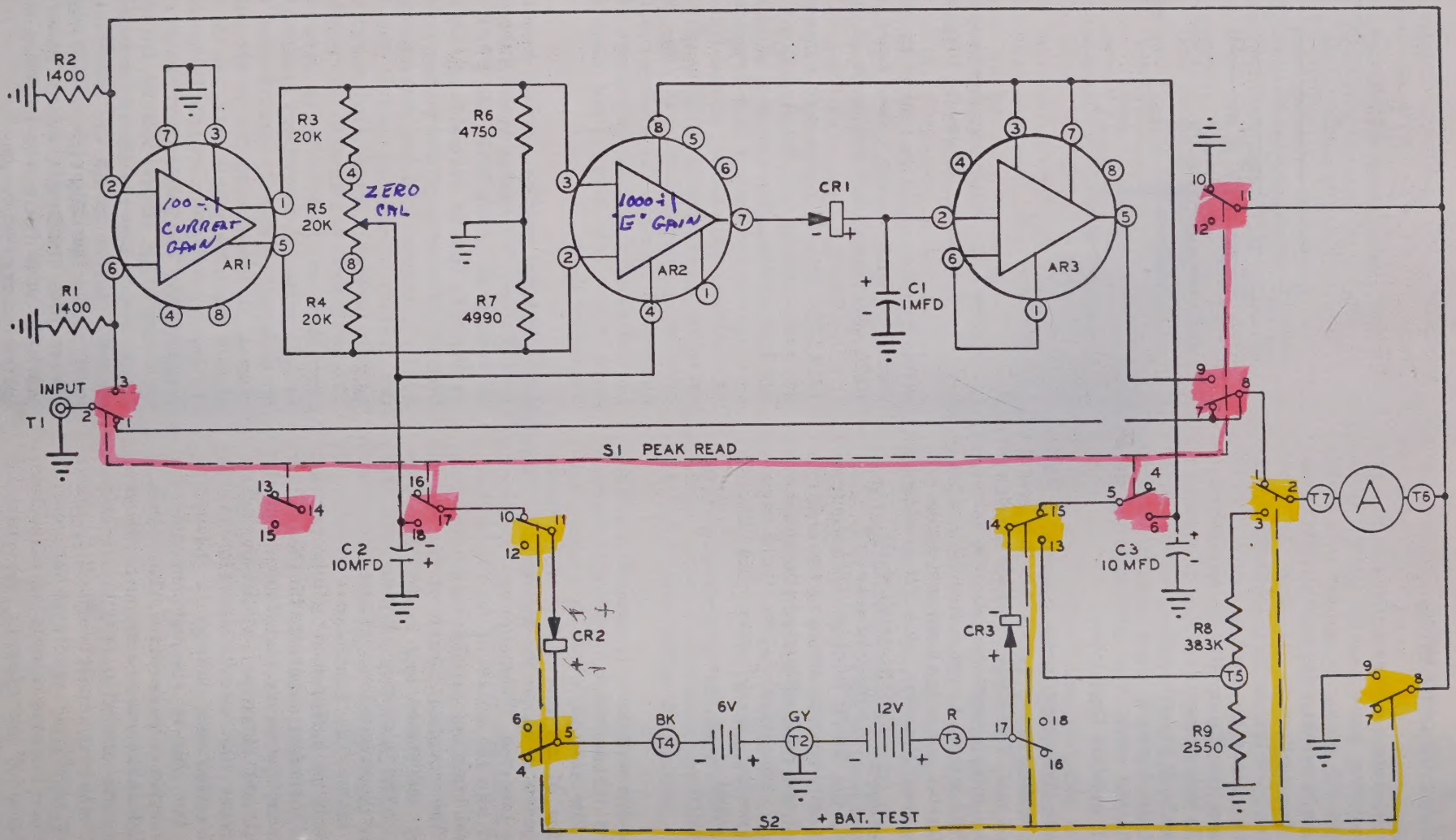


Figure 1-3. Peak Reading Amplifier, Schematic Diagram

1-19. The amplifier circuit is designed to provide current to the meter which will indicate at a steady state the peak of the power applied to resistor R1. Resistor R1 exactly matches the resistance provided meter M1, so that the existing circuit in the plug-in element is loaded exactly the same as during average reading mode.

1-20. When switch S1 is pressed, the dc input which is normally applied to the meter is interrupted and is applied instead to resistor R1 and differential amplifier AR1 which gives a current gain of approximately 100:1. This output is applied to a resistance bridge consisting of resistors R3, R4, R5, R6, and R7. Variable resistor R5 of this bridge permits zero calibration of the amplifier circuit. Bridge output is applied to differential amplifier AR2 which provides a voltage gain of about 1000:1. The voltage gain ratio of this is extremely important in determining the minimum pulse duration which can be indicated, since it is the surge of voltage from this amplifier which charges capacitor C1. Capacitor C1 applies a potential to differential amplifier AR3 as long as the capacitor remains charged This amplifier provides a massive current gain ratio, but unity or slightly less voltage gain. This is applied to meter M1 to indicate the peak of the line input. A portion of the dc output of amplifier AR3 is fed back to resistor R2 and to amplifier AR1. Resistor R2 is matched to resistor R1 to within a tolerance of 0.2 percent to provide unity gain to the amplifier. This feedback circuit maintains the output from AR1 and in turn from AR2 to keep capacitor C1 charged to that value which yields unity closed loop gain. The capacitor continues to energize AR3 to maintain the reading of the meter even though the peak of the pulse is no longer applied to the amplifier assembly input. In this manner, only peak power is indicated, even though there is a wide fluctuation of input power.

1-21. Because of capacitor leakage, diode back resistance, and transistor input current (low as it may be), there will be a decay in the circuit to limit the time the amplifier system will retain its output level. As the circuit decays, the meter will return to zero provided no additional pulses are received at resistor R1.

SECTION II
PREPARATION FOR USE

2-1. BATTERY INSTALLATION

2-2. This wattmeter uses battery power to operate the amplifier which provides peak watt readings. Two batteries are required. Refer to Table I, Leading Particulars, for a listing of battery type requirements.

2-3. To install batteries, proceed as follows:

a. Remove the six machine screws that secure the wattmeter back to the housing. Carefully pull the back from the housing.

CAUTION

Careless removal of the wattmeter back will break the wires that connect the batteries to the amplifier.

b. Open the metal retaining strap and insert batteries in position, carefully observing the polarity markings on the battery bracket (see figure 2-1).

c. When batteries are positioned in the brackets provided, install the retaining strap to retain them.

CAUTION

After batteries are installed, make sure the unit is not allowed to stand unused with the PEAK READ switch pushbutton in the down position. Battery life with the button down is approximately 50 hours.

d. Press the BATTERY TEST pushbutton and watch the meter indication. The meter pointer must move to the area to the right of the BATTERY TEST mark. This indicates that sufficient battery power is available to operate the amplifier circuit. If the meter fails to indicate to the required level with new batteries, it is probably due to incorrect installation of the batteries, or battery leads that were damaged due to rough handling. Reposition the batteries, carefully following the polarity markings, or repair damaged leads.

e. When proper meter indications are attained, install the meter back panel with six machine screws.

2-4. WATTMETER INSTALLATION

2-5. Wattmeter Model 4311 is a portable instrument, not specifically designed for attached mounting. It is designed with a leather carrying strap to facilitate movement from one location to another. When transporting the wattmeter, turn the plug-in element in the line section of the meter so that the arrow points up. This will shunt the meter connection circuit and dampen needle action during handling and shipment.

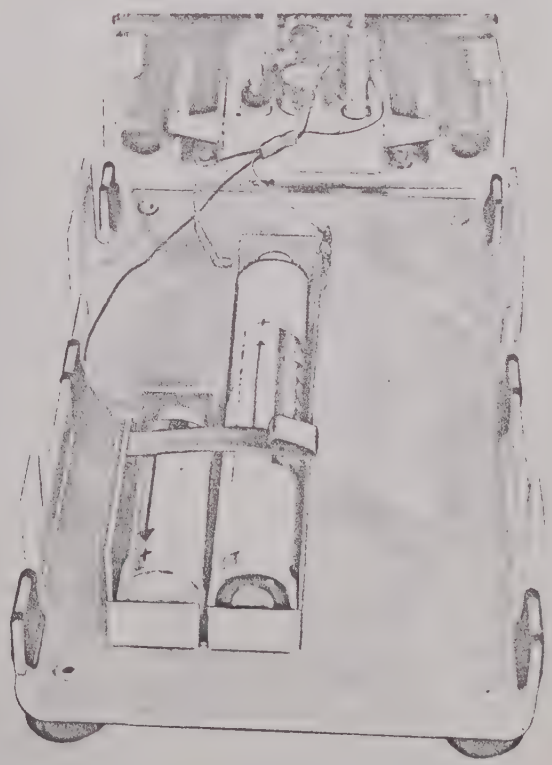


Figure 2-1. Battery Installation

Make sure the spare plug-in elements are securely mounted in the sockets of the unit. Secure with the thumbscrews provided. Figure 2-2 shows wattmeter dimensions.

CAUTION

Dropping or rough handling of the wattmeter plug-in elements will disrupt the calibration. Handle them with reasonable care at all times. The microammeter is shock mounted in the housing, but dropping or other severe impact can damage the delicate mechanism of the meter.

2-6. Install the wattmeter into an RF circuit having a 50-ohm impedance only. Connecting into lines of other impedance values will cause a mismatch, resulting in seriously inaccurate readings. Avoid this condition if possible. In case of exceptional need, the unit can be connected to lines of mismatched impedance. Refer to paragraph 3-21 for an indication of the degree of inaccuracy caused by this mismatch.

2-7. CONNECTIONS

2-8. The line section of the wattmeter is normally fitted with two female "N" type connectors. Connections are readily made using male "N" type cable plugs. However, other types are available from Bird Electronic Corporation as required. The quick-change connectors can be replaced by removing the four screws from each corner of the square flanges of the connector and pulling straight outward, carefully disengaging the spring fingers of the center conductor. Install the new connector by reversing the removal procedure. The alternate connectors available are listed in the parts section in the back of this manual.

2-9. Normally, the RF line is connected to the threaded ends of the line section of the wattmeter. No other connections are required for operation. Take care that the plug-in element installed in the socket of the line section has a sufficient watt rating to indicate the line load when the load is applied to the RF line. Severe damage to the plug-in element or meter can result from a mismatch between the watt rating of the element and the line.

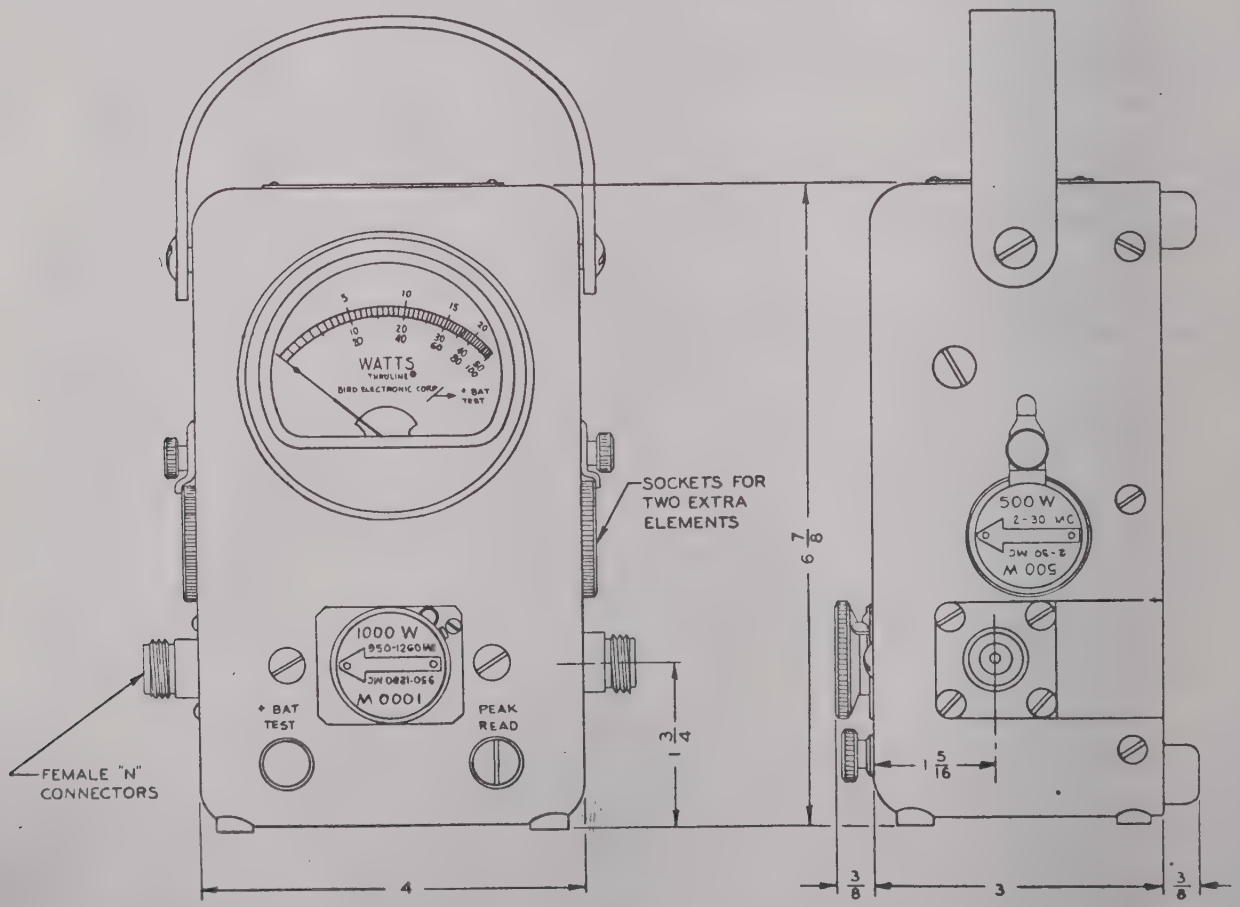


Figure 2-2. Wattmeter Dimensions

SECTION III
OPERATING INSTRUCTIONS

3-1. CONTROLS AND INSTRUMENTS

3-2. The location, purpose, and use of operating controls and instruments are given in Table III and figure 3-1.

3-3. ZEROING THE METER

3-4. Before taking any readings with the wattmeter, it is necessary to zero the meter under no-power conditions. Proceed as follows:

a. Rotate the plug-in element (6, figure 3-1) so that the arrow points up.

b. Using a small screwdriver, turn the meter zero screw (9) clockwise or counterclockwise as necessary so that the meter pointer exactly aligns with the zero of the meter scale.

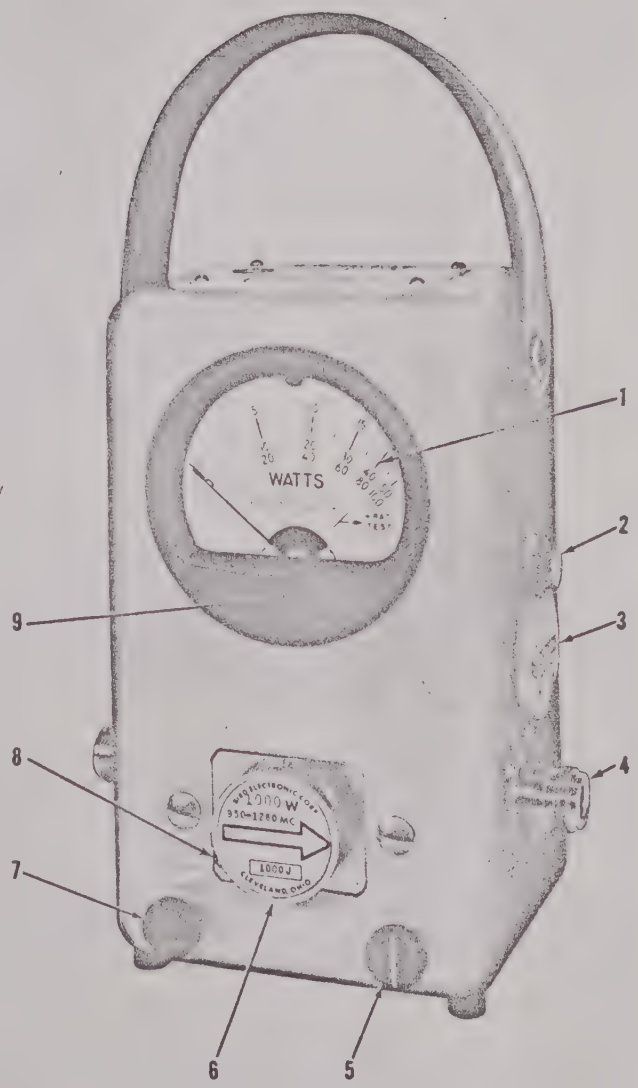
3-5. PLUG-IN ELEMENT SELECTION AND INSERTION

3-6. Use a plug-in element (6) which has a high enough wattage rating and the required frequency range to properly indicate the power of the RF line. If the approximate wattage of the line is not known, start with an element which will be sure to adequately cover the maximum wattage of the transmitter to prevent overloading the wattmeter. Substitute a lower reading element for the first element it its indicating range is too high for accurate power determination. Remove and insert elements as follows:

a. Loosen the spare element retaining screw (2, figure 3-1) to release the clip which retains the spare element (3) in the side of the wattmeter. Remove the spare element.

b. Release the catch (8) that secures the element in the line section body of the wattmeter; remove the element (6).

c. Hold the catch in the released position and insert the replacement element in the line section body. Release the catch to retain the replacement element. Install the removed element in the spare element socket and retain with the spare element retaining screw (2).



1. Wattmeter
2. Spare Element Retaining Screw
3. Spare Plug-In Element
4. RF Line Connector
5. PEAK READ Switch
6. Plug-In Element
7. + BAT TEST Switch
8. Element Catch
9. Meter Zero Screw

Figure 3-1. Wattmeter Controls

TABLE III. CONTROLS AND INSTRUMENTS

Index No. Fig. 3-1	Control Name	Purpose and Use
1	Meter	Indicates watts sensed by the instrument. Contains three scales proportional to ratings of various plug-in elements.
3	Spare Plug-In Element	When it replaces the installed plug-in element, it changes the wattage and/or frequency ranges of the instrument.
5	PEAK READ Switch	In normal position, meter indicates average wattage. When operated, meter indicates peak pulse power or peak envelope power.
6	Plug-In Element	Determines whether forward or reflected waves are being sensed. When arrow points to load, instrument senses forward waves. When arrow points to transmitter, instrument senses reflected waves.
7	+ BAT TEST Switch	When depressed, it causes meter to indicate state of battery charge.
8	Element Catch	Retains and releases plug-in element in element socket of line section.
9	Meter Zero Screw	Provides a zero adjustment for the meter.

3-7. DETERMINING AVERAGE LOAD POWER

3-8. This wattmeter provides easy measuring or monitoring of transmitter power. Assuming that the proper element is installed in the wattmeter and that the RF lines are connected to the threaded ends of the wattmeter, determine average load power as follows:

a. Rotate the plug-in element (6, figure 3-1) so that the arrow on the element points in the line direction of the load. Note the reading given on the meter (1). This is the forward power.

b. Rotate the plug-in element so that the arrow on the element points in the line direction of the transmitter. Note the reading given on the meter. This is the reflected power.

c. Subtract the reflected power from the forward power to get watts delivered to and dissipated in the load as follows:

Watts (load) = Watts (forward) - Watts (reflected)

d. The importance of the reflected power varies depending upon the load. Where appreciable power is reflected, as with an antenna, the subtraction of the reflected power is necessary to obtain a true average wattage reading. However, this step may be unnecessary when the load is a good resistor so that the reflected power becomes negligible (less than 1 percent).

3-9. DETERMINING PEAK POWER

3-10. To determine peak pulse power or peak envelope power of the traveling waves, proceed as directed in 3-6 above for average power, except that the PEAK READ switch (5) must be operated to peak reading.

CAUTION

After using the wattmeter in the peak reading mode, be sure to release the PEAK READ switch so that the switch button is up. Battery life with the button down is approximately 50 hours. Releasing the button will extend calendar life of the batteries.

3-11. DETERMINING VSWR

3-12. This unit is not designed to provide direct VSWR (volts-standing-wave-ratio) readings. It is felt that VSWR readings are no more valuable than the ratio of forward to reflected power. In fact, most operators find that in transmitter tune-up, antenna matching, and similar problems dealing with RF circuits, the forward power-to-reflected power ratio is a

highly useful tool. However, VSWR readings can be determined by use of graphs as follows:

a. Determine the forward power and the reflected power as directed in paragraph 3-4.

b. Refer to the appropriate graph (figure 3-2 or 3-3) to convert the forward wattage reading and the reflected wattage reading to VSWR. Note that the graphs convert the readings directly into VSWR values without any intermediate computations.

3-13. MAKING LOW REFLECTION READINGS

3-14. When checking TV transmission antenna lines and VHF Omnirange transmitters, it is often desirable to make very accurate low reflection readings. This can be done using two elements, provided that care is taken to prevent application of high forward power to the low-reading element. This procedure is limited to use with higher powered transmitters only. Proceed as follows:

a. Measure watts forward, using the proper plug-in element. Reverse the arrow direction of the element and get a reading to determine the general level of reflected power.

b. Remove the plug-in element and insert a second, lower reading element which has a maximum rating of more than the reflected power indicated in step a above. Insert the element so that it reads reflected power only.

CAUTION

When making low reflection readings using two elements, take care to insert the lower reading element so that it senses reflected power only. Do not rotate the lower reading element in the socket so that it is subjected to forward power. This will result in damage to the plug-in element, to the microammeter, or both.

c. Read the reflected power on the meter in the usual manner.

d. When using the two-element method of reading low reflected power, do not use a pair of elements which has a difference of greater than 10 to 1, or, at the very greatest, 25 to 1.

3-15. FREQUENCY RESPONSE

3-16. Each plug-in element of the wattmeter is designed to operate within a specific frequency range. The use of these elements to measure direct power outside of the stated frequency range is not recommended. The frequency response of the elements is very flat over their designated range, as shown in figure 3-4. Note that the fall-off above and below the assigned frequency range is greater for low-power elements than for high-power elements. The curves shown in figure 3-4 may be assumed to be typical for all listed band types (see Table II).

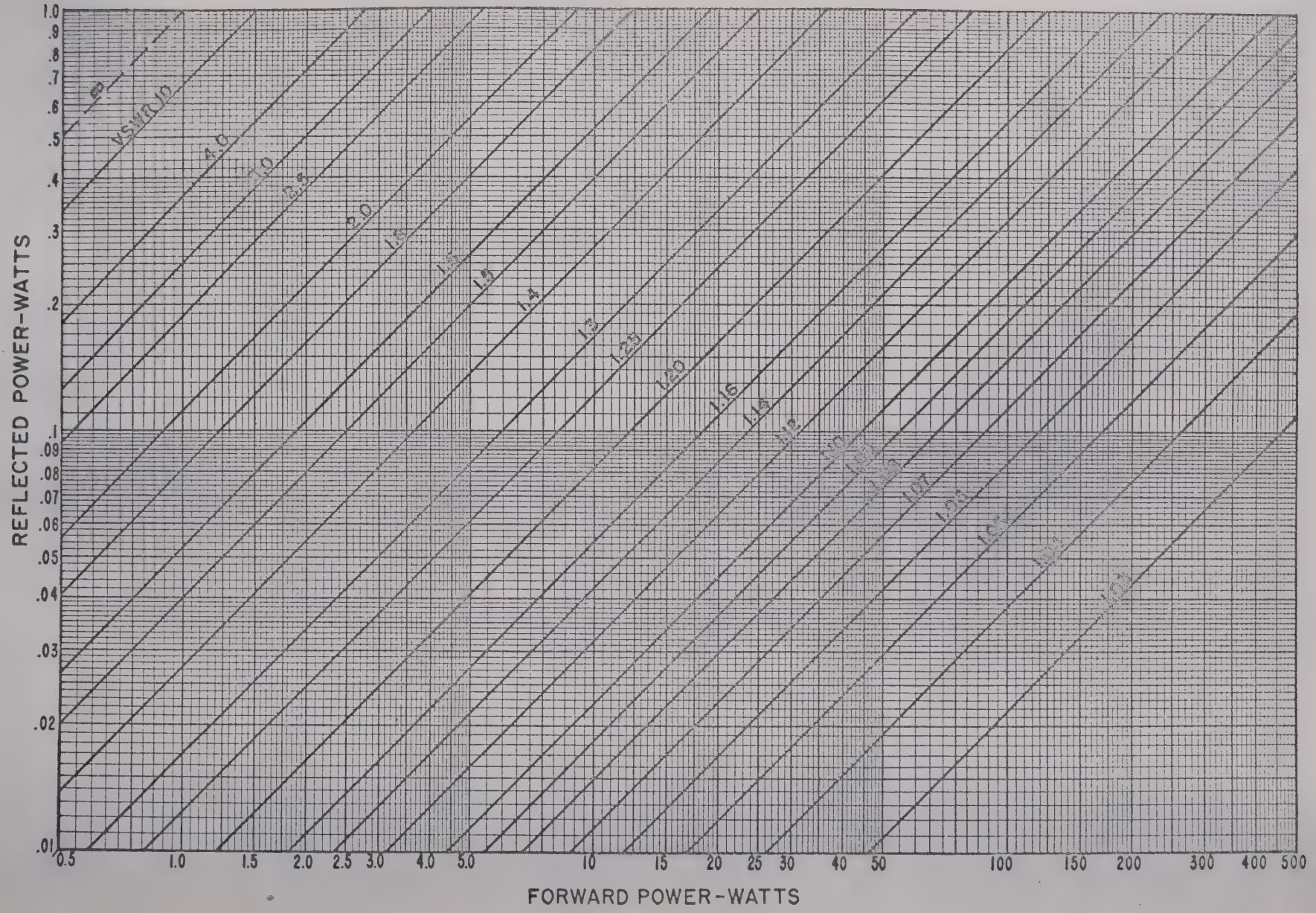
3-17. Harmonics outside of the element frequency bank may be known to exist in the measure circuit. If so, a rough approximation of the response of the element to these harmonics can be made using the curves shown in figure 3-4. The frequency ordinate on the graph will be obtained by proportioning the frequency of the element used with that of the one illustrated. Interpolate the curve values to get an approximation of the strength of the harmonic signals being measured by the element.

3-18. TESTING LINES, CONNECTORS, FILTERS, AND RELATED COMPONENTS

3-19. Lines, connectors, filters, and related components can be tested using the Thruline Wattmeter, Model 4311. The method of testing used depends upon the circumstances involved for any particular test. Some of these tests are as follows:

a. The standing wave ratio or the reflected power-to-forward power ratio of a line can be determined by terminating the line with a good load resistor, such as a Termaline. Proceed as described in paragraph 3-5. Low reflected power may be measured as described in paragraph 3-14.

b. Line attenuation (power lost by heat in the line) can be determined by inserting the line of unknown value between two wattmeters or between two wattmeter line sections. If the latter method is used, one wattmeter unit and one element can be used to make both readings. In either case, the end of the line must be terminated by a load resistor. By comparing readings made at the two places, the attenuation of the line can be determined. Where very small values of attenuation are involved, allowances must be made for normal instrument error. Slight juggling of zero settings is permissible for convenience of eliminating computations, provided the readings are fairly high on the meter scale.



FOR HIGHER POWER VALUES MULTIPLY BOTH SCALES BY THE SAME DECIMAL FIGURE

Figure 3-2. Power Values vs VSWR (Reflected Power 0.01 to 1.0 Watts).

Attenuation can also be determined by the
n circuit method. The wattmeter exhibits
d equality between forward and reflected
dings when the load connector is open or
rt circuited. When this is checked on an
n circuit and an open circuited length of
of unknown attenuation is connected to the
d connector, the new ratio shown is the
nuation in two passes along the line (down
back). This can be converted to decibels
ollows:

$$\text{Attentuation (decibels)} = 10 \log \frac{\text{forward power}}{\text{reflected power}}$$

e decibel reading must be halved because
ce the line length is being measured (down
d back). This measurement must be supple-
nted with a reflected power-to-forward power
io check (subparagraph a above) or with a
continuity check or leakage check, since open
cuits or shorts may exist part of the way
ng the line.

Attenuation can also be determined as des-
bed in c above by using a short circuit
her than an open circuit. The open circuit
thod is preferred because the initial equality (forward power-to-reflected power) is more easily achieved in an open circuit.

3-20. MEASURING PERCENTAGE OF POSITIVE MODULATION

3-21. Measuring the percentage of positive modulation in an amplitude modulation system is easily done by employing the average and peak reading characteristics of the unit, since:

Percent pos. mod. =

$$\frac{\text{E max - E carrier}}{\text{E carrier}} \times 100$$

By substitution we get:

Percentage pos. mod. =

$$\frac{\sqrt{P_p} - \sqrt{P_c}}{\sqrt{P_c}}$$

When:

P_p = peak power as read with PEAK READ switch down.

P_c = carrier power as read with PEAK READ switch up.

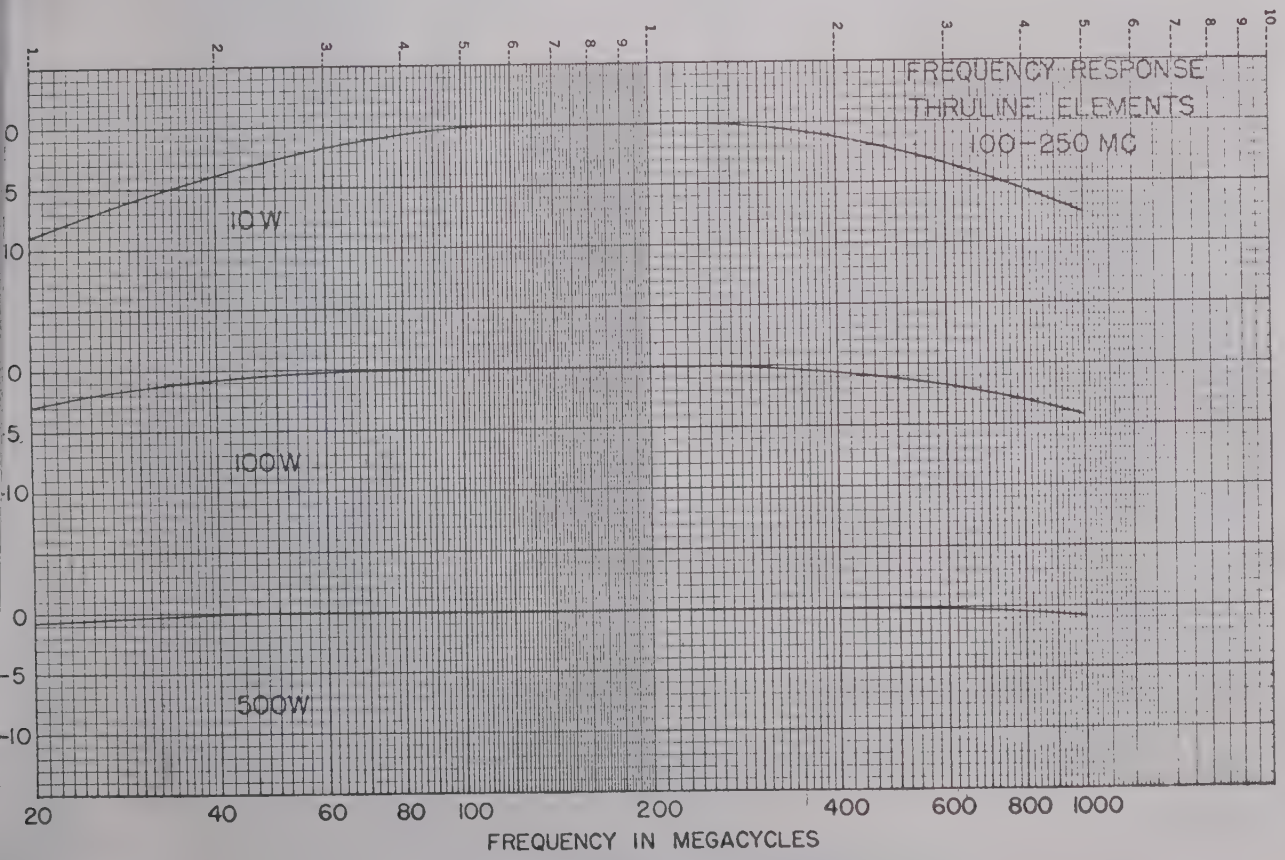
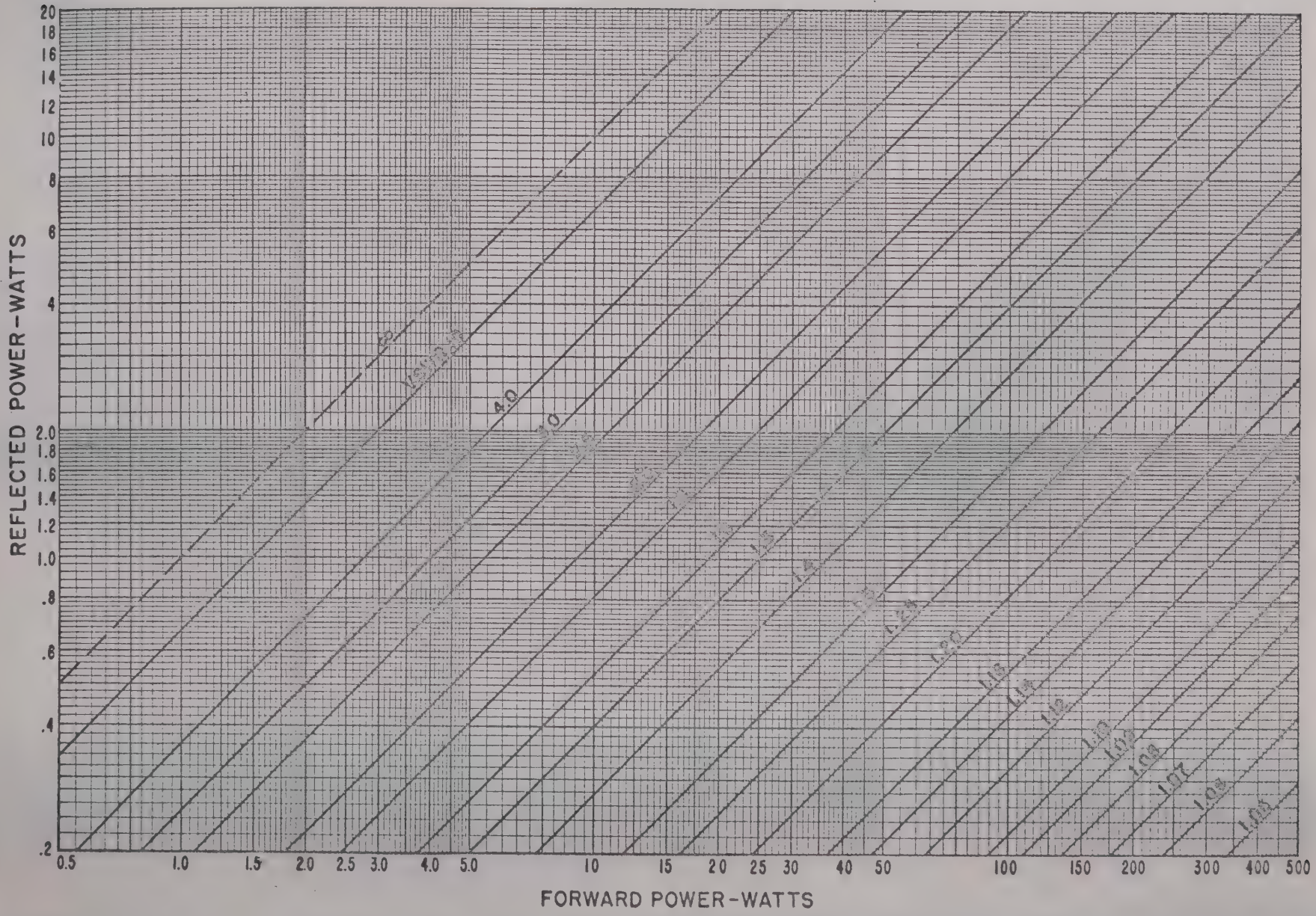


Figure 3-4. Wattmeter Response at Various Frequencies



FOR HIGHER POWER VALUES MULTIPLY BOTH SCALES BY THE SAME DECIMAL FIGURE

or:

$$\text{Percent pos. mod.} = \frac{\sqrt{P_p}}{\sqrt{P_c}} - \frac{\sqrt{P_c}}{\sqrt{P_c}} \times 100$$

and by cancellation

$$\text{Percent pos. mod.} = \frac{\sqrt{P_p}}{\sqrt{P_c}} - 1 \times 100$$

These computations are shown graphically in figure 3-5. After determining average and peak readings, consult the graph to determine the percentage of positive modulation.

3-22. IMPEDANCE MISMATCH

3-23. This wattmeter is designed to check power in a 50-ohm circuit. When the wattmeter is connected into the RF line, it inserts a 4-inch section of 50-ohm line into that circuit. When this is inserted into a line having an impedance other than 50 ohms, the load on the transmitter will change because of the insertion. This change is not too serious if the power reflection factor is less than 10 percent or if the frequency is less than 200 mcs. At values higher than these, the insertion of the 50-ohm line will result in a very different load impedance even if the transmitter is tuned up with the wattmeter inserted into the line. The wattmeter will indicate zero reflection when the unit is connected into a 50-ohm, pure resistive line. When a 70-ohm line is connected on the load side of the wattmeter, under ideal conditions, the 50-ohm wattmeter will indicate 3 percent reflected power or a VSWR of 70/50 = 1.4. The wattmeter can show this same reflected percentage when a 50/1.4 = 35.7-ohm, pure resistive load is applied to the 70-ohm line. This could exist with 10 percent reflected power on the 70-ohm line (VSWR = 2). From this it can be seen that when the 50-ohm wattmeter is applied to a 70-ohm line, the line could have 10 percent reflected power with a VSWR of 2.0, but the meter would indicate only 3 percent reflected power (VSWR = 1.4). If it is necessary to make wattage readings on a 70-ohm line with the 50-ohm wattmeter, it is especially important to subtract the reflected power from the forward power.

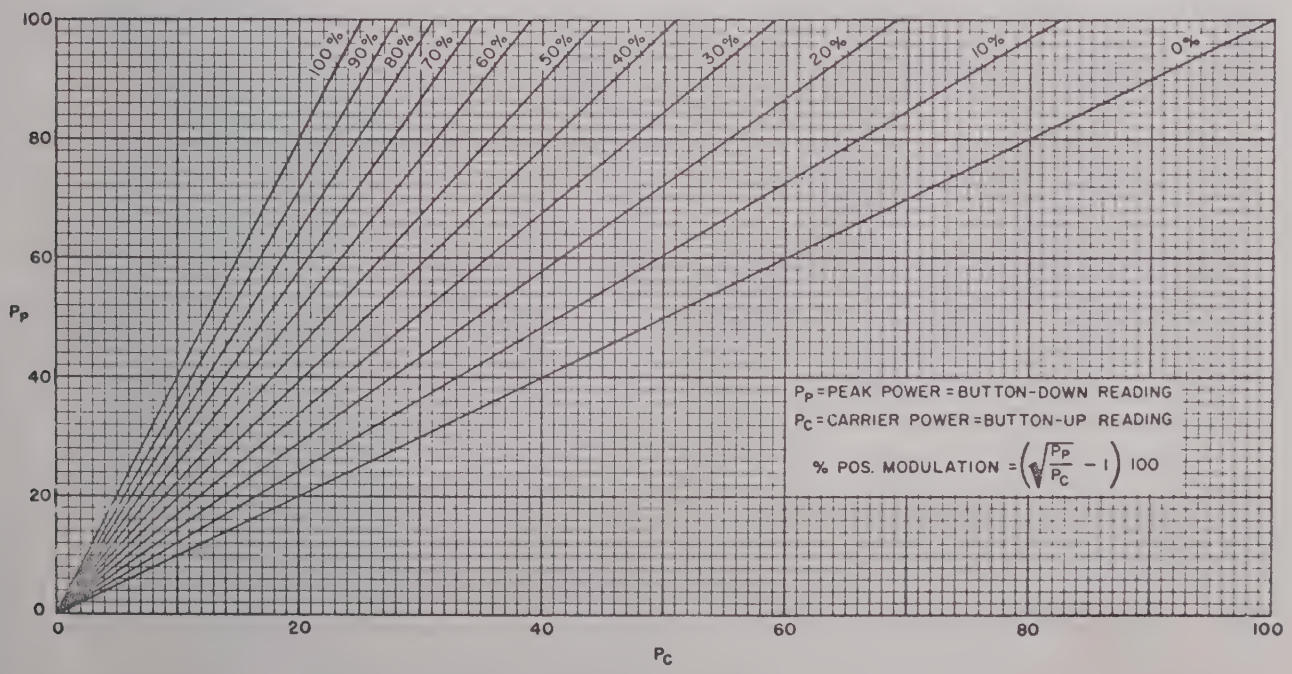


Figure 3-5. Graph Converting Carrier Power and Peak Power to Percent Positive Modulation

SECTION IV
MAINTENANCE INSTRUCTIONS

4-1. MAINTENANCE

4-2. Maintenance of the Thruline Wattmeter Model 4311 is normally limited to cleaning. The amount of cleaning necessary can be minimized by taking the following precautions:

a. Keep the plug-in element in the socket of the line section as much as possible. This serves as an effective seal against the entry of dust and dirt. Cover the socket opening when the element is removed.

b. Protect the RF connectors on the line section against the entry of dust and dirt by keeping them connected to the line or by covering them when the line is disconnected.

4-3. CLEANING

4-4. All contacts must be kept clean to assure low resistance connections to and within the unit. Clean contacts as follows:

a. Clean RF connectors with a cotton swab stick dampened with carbon tetrachloride.

WARNING

Do not use any solvent other than carbon tetrachloride for cleaning the wattmeter. When using this fluid, avoid inhalation of fumes and avoid unnecessary and repeated contact with the skin.

b. Clean the inside of the line section socket bore and the entire circumference of the plug-in element with a cotton swab stick dampened with carbon tetrachloride. Pay particular attention to the cleaning of the bottom rim of the element body and to the seat of the socket in the line section.

c. When cleaning the socket bore, take care not to disturb the spring finger of the dc contact. If necessary, the spring finger of the dc contact can be adjusted manually. The button must be positioned out far enough to make good contact with the element body, but it must not restrict the entry of the element body. Remove two machine screws that secure the dc jack to the line section. Remove the dc jack from the line section, taking care not to lose the small positioning bead that straddles the base of the phosphor bronze spring and nests in a counterbore on the side of the RF body. After adjusting to meet the requirements, make sure that the bead is properly inserted.

d. Check the inside of the line section for dirt and contamination. Clean the reachable portions of the line section with a cotton swab stick. Blow out the remaining dirt with low-pressure, dry compressed air.

CAUTION

Do not attempt to remove the RF line conductor from the line section. Any attempt to remove it will ruin the assembly.

SECTION V
TROUBLESHOOTING

5-1. TROUBLESHOOTING CHART

5-2. Table IV, Troubleshooting Chart, provides a list of the most probable causes of trouble which might develop in the wattmeter. For each trouble there is a list of probable causes and remedies. Refer to the troubleshooting chart in the event of trouble in the unit.

TABLE IV. TROUBLESHOOTING CHART

TROUBLE	PROBABLE CAUSE	REMEDY
NO METER INDICATION (AVERAGE OR PEAK)	Arrow on plug-in in wrong direction.	Correct arrow direction.
	No radio frequency power.	Check transmitter for faults.
	No pickup from dc contact finger in line section.	Adjust finger (par. 4-4c).
	Open or shorted dc meter cable.	Replace cable.
	Meter burned out or damaged.	Replace meter.
NO METER INDICATION (PEAK ONLY)	Battery leads broken.	Repair battery leads.
	Defective component in amplifier section.	Replace defective component.
INTERMITTENT OR INCONSISTENT METER READINGS	Faulty load.	Correct fault in load.
	Faulty transmission line.	Correct fault in transmission line.
	Dirty dc contacts on elements.	Clean dc contacts (par. 4-4).
	Sticking or defective meter.	Replace meter.
HIGH PERCENTAGE OF REFLECTED POWER	Faulty load.	Correct fault in load.
	Poor connectors.	Check for high resistance connections.
	Shorted or open transmission line.	Correct fault in transmission line.
	Foreign material in line section.	Clean line sections thoroughly (par. 4-4).

SECTION VI
CALIBRATION

6-1. GENERAL

6-2. Thruline Wattmeter Model 4311 normally requires no calibration other than zeroing of the meter. This should be done any time the meter pointer is not exactly aligned with the zero mark on the meter scale when no readings are being made. Any other adjustments are discouraged unless one or more components are replaced in the amplifier section. If this has been done, proceed as directed in paragraph 6-4 below.

6-3. AVERAGE-TO-PEAK VOLTAGE LEVEL ADJUSTMENT

6-4. To assure that the meter reads correctly for both average and for peak operation, a direct current from a battery source is applied to the input of the amplifier circuit. Refer to figure 1-3. The steady direct-current peak level should be the same as the average current level, because no peaks exist in this current. Apply a direct current and adjust as necessary so that the same reading is attained in both average and peak modes. Proceed as follows:

a. Install a voltage-dropping variable potentiometer and a battery in series with the input of the amplifier. Make sure the resistor is set for zero output. Connect the positive (+) side of the circuit to input and the negative (-) side to ground. Install a voltmeter across the circuit. Slowly operate the potentiometer to adjust output to apply exactly 21 millivolts. A suitable resistive network must be used to assure that the battery voltage is properly reduced. ✳

b. Check the reading of the meter. It should indicate about half of total scale reading. Press the pushbutton of PEAK POWER switch S1 while watching the meter pointer. There should be no deviation of the pointer from average to peak reading.

c. If the pointer reads a different value for peak reading than for average reading, rotate the adjusting cap on resistor R5 on the amplifier until the two readings coincide.

✳ Meter input very sensitive to noise pulses. Place .01μf cap across leads near input connector to [illegible] K.D. 7-8-13

SECTION VII
REPAIR INSTRUCTIONS

7-1. GENERAL

7-2. Repair of the Thruline Wattmeter Model 4311 consists primarily of soldering of broken leads and replacement of faulty parts and assemblies. Because most parts are operating at levels much lower than their rated levels, the frequency of part replacement is very low, provided the unit is properly handled, not subjected to excessive loads, and properly maintained. If repair or parts replacement is required, follow procedures consistent with good electronic repair practice.

7-3. When replacing components, make sure to use parts which have the same ratings and tolerances as the parts being replaced. Failure to use parts having the required ratings and tolerances will result in widely divergent readings on the meter.

7-4. METER REMOVAL AND REPLACEMENT

7-5. Replace the meter as follows:

a. Carefully remove the back panel from the meter. Disconnect the leads from the meter terminals. These are friction-type slip-on connections.

b. Remove the two machine screws that hold the meter at the sides of the meter housing. Lift the meter from the housing.

c. Position the new meter in the housing; secure with two machine screws. Connect the leads of the meter cable to the meter, making sure the color codings on the meter coincide with the wire colors. Install the back panel on the meter housing.

7-6. AMPLIFIER REMOVAL AND REPLACEMENT

7-7. Remove and replace the amplifier assembly as follows:

a. Remove the back panel from the meter. Disconnect the three battery cable leads from the terminals of the amplifier. Disconnect the two meter cable leads from the terminals of the amplifier.

b. Disconnect the dc lead cable from the amplifier input terminal.

c. Remove the four machine screws that secure the amplifier assembly to the bottom of the housing. Lift the amplifier assembly from the housing.

d. Position the new or repaired amplifier assembly in the housing; secure with four machine screws.

e. Connect the leads of the battery cable and from the meter cable to the terminals of the amplifier, taking care to match the color codings of the terminals with the color codings of the cable leads.

f. If major components of the amplifier have been replaced, calibrate the amplifier as described in paragraph 6-4.

g. After calibration, connect the dc cable between the amplifier and the line section.

h. Install the back panel on the meter assembly.

7-8. AMPLIFIER ASSEMBLY REPAIR

7-9. When repairing the amplifier, pay particular attention to the following:

a. If soldering of the amplifier components is required, either remove all plug-in amplifiers or unplug the soldering iron before soldering.

b. The integrated circuits which comprise AR1, AR2, and AR3 are color coded to the chassis, with AR1 and AR3 being identical and interchangeable, and therefore having the same color codes. Take care not to interchange AR2 with either AR1 or AR3. The color codes also provide the key for polarity of the integrated circuits. The color dot on the unit must match the position of the color dot on the chassis to assure proper polarity. No other polarity key exists for these units.

CAUTION

If amplifier AR2 is interchanged with either amplifier AR1 or AR3, it will apply excessive loads throughout the amplifier and result in extensive component damage. Also, the polarity of integrated circuits is extremely critical. If installed in the socket incorrectly, it will also overload circuits and cause extensive damage. Always insert the integrated circuit so that color matches color and so that color dot position on the integrated circuit matches the color dot position on the amplifier chassis.

c. When soldering components of the amplifier, take care to prevent damage due to excessive heat. Always use a pair of long-nosed pliers or tweezers between the solder connections and diodes to provide a heat sink when soldering diodes into place.

d. If either resistor R1 or R2 is damaged, replace both of the parts as a matched set. Unless these are replaced as a matched set, the peak wattage indications of the meter may be grossly inaccurate.

SECTION VIII
REPLACEMENT PARTS LIST

8-1. GENERAL

8-2. The parts lists in this section list the replacement parts for the wattmeter. The parts lists are supported by figures 8-1 and 8-2 which illustrate all replacement parts of the unit. The last column of the list provides the reference designation identification of the applicable parts. Refer to the schematic diagram in figure 1-3 to cross-reference the parts list to the equipment.

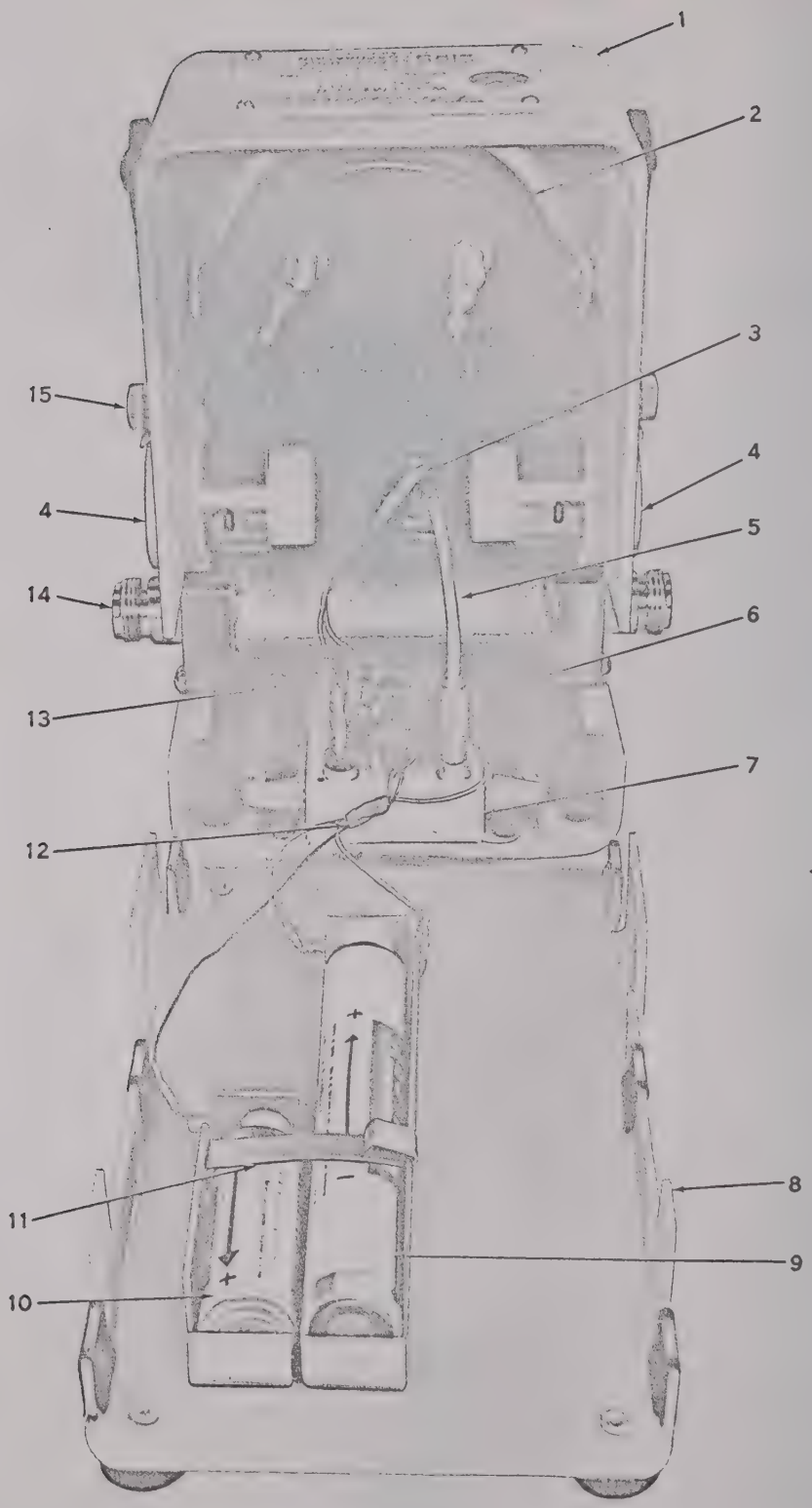
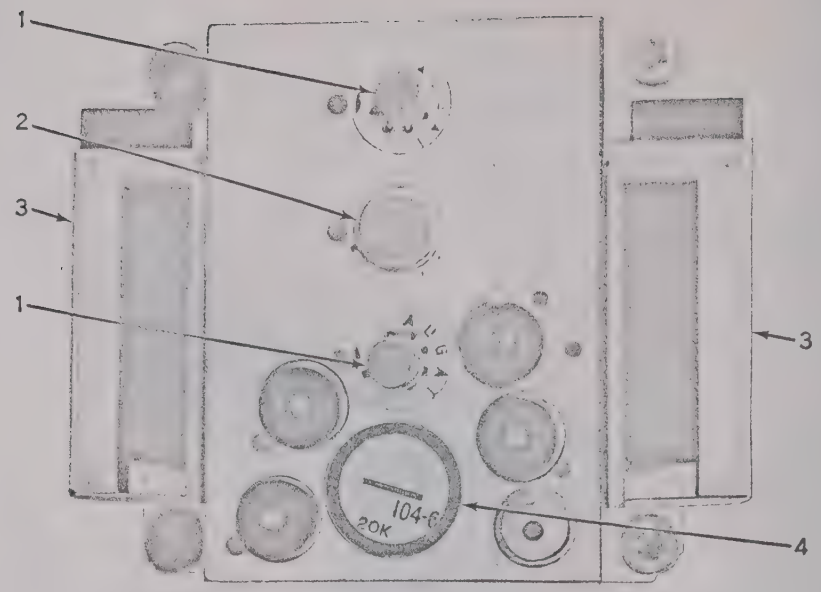


Figure 8-1. Wattmeter Replacement Parts

FIG. & INDEX NO.	BIRD PART NO.	DESCRIPTION	UNITS PER ASSY	REF. DESIG.
8-1-1	4311-003	HOUSING ASSEMBLY	1	
-2	208011	METER	1	M1
-3	4311-048	HARNESS, Meter hookup	1	
-4	NOTE 1	ELEMENT, Plug-in	AR	
-5	4311-036	CONNECTOR AND CABLE ASSEMBLY, Dc	1	
-6	4311-053	PUSHBUTTON KIT, Battery test	1	
-7	4311-004	AMPLIFIER ASSEMBLY (See figure 8-2 and associated list for breakdown)	1	
-8	4311-022	COVER ASSEMBLY, Housing	1	
-9	5-492	BATTERY, 12.6 V (P. R. Mallory No. TR-169)	1	
-10	5-493	BATTERY, 5.4V (P. R. Mallory No. TR-164R)	1	
-11	4311-003	CLIP, Battery	1	
-12	4311-047	HARNESS, Battery hookup	1	
-13	4311-054	PUSHBUTTON KIT, Peak read	1	
-14	4311-032	LINE SECTION ASSEMBLY	1	
-15	4311-052	CLAMP KIT, Spare element	1	

NOTE 1. A large selection of plug-in elements is available covering a wide range of frequencies and wattages. Refer to Table II. Order these parts by giving frequency and wattage. range required.



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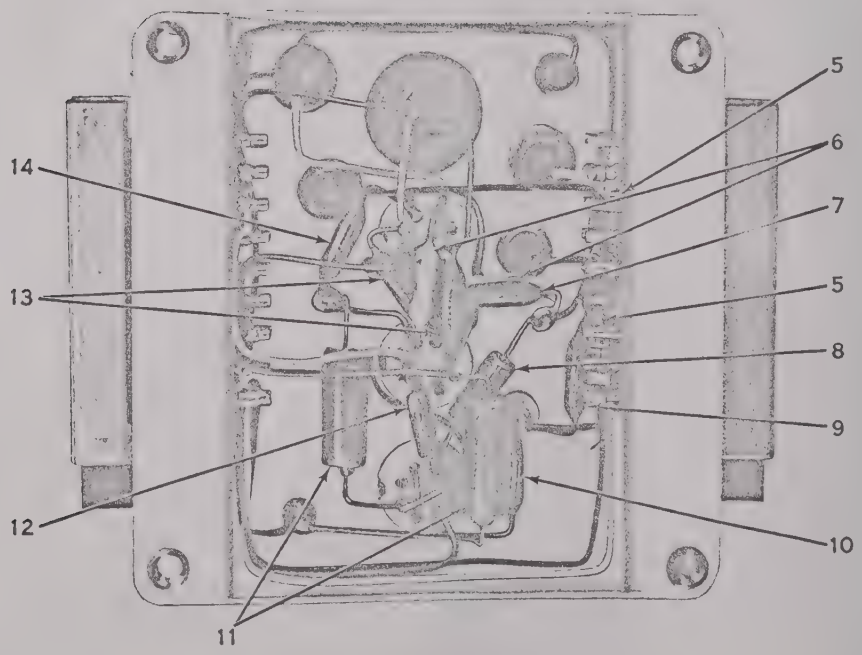

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Figure 8-2. Amplifier Replacement Parts

FIG. & INDEX NO.	BIRD PART NO.	DESCRIPTION	UNITS PER ASSY	REF. DESIG.
8-2-1	4311-049	AMPLIFIER, Differential	2	AR1, AR3
-2	4311-050	AMPLIFIER, Differential . . . . . 710HC . . .	1	AR2
-3	5-497	SWITCH (Chicago Switch No. 203-006-018)	2	S1, S2
-4	5-496-7	POTENTIOMETER (IRC Model 104-6 20K)	1	R5
-5	5-526-2	DIODE (Fairchild Semiconductor Type FD700) . . .	2	D2, D3
-6	5157	RESISTOR SET, Matched	1	R1, R2
-7	5-521-4	RESISTOR (IRC Type CEA T-O, 1/8W, 4990 ±1%) .	1	R7
-8	5-525-1	CAPACITOR (Sprague No. CS13-BF105K, 1 uf) . .	1	C1
-9	5-521-2	RESISTOR (IRC Type CEA T-O, 1/8W, 383K ±1%) .	1	R8
-10	5-521-3	RESISTOR (IRC Type CEA T-O, 1/8W, 2550 ±1%) .	1	R9
-11	5-5222-1	CAPACITOR (Sprague)No. CS13-BE106K, 10.0 uf) .	2	C2, C3
-12	5-526-1	DIODE (Fairchild Semiconductor Type FD600) . . .	1	D1
-13	5-521-1	RESISTOR (IRC Type CEA T-O, 1/8W, 20K ±1%) . .	2	R3, R4
-14	5-521-5	RESISTOR (IRC Type CEA T-O, 1/8W, 4750 ±1%) .	1	R6

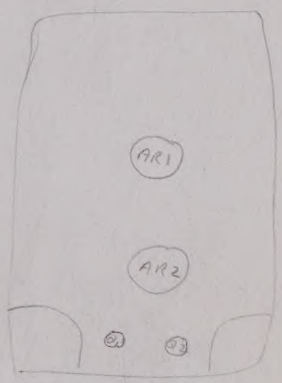
SOME MODELS

4311-058 · amplifier AR1 DUAL TRANSISTOR

4311-050 " AR2 OP AMP 710

4311-056 Transistor Q_1, Q_2

4311-005 PC BOARD



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